Fingerling release program, biomass trend and evolution of the condition factor of Caspian Kutum during the 1991-2011 period

by

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ABSTRACT. - This paper examines the changes in biomass and condition index in relation to stock enhancement of Kutum (*Rutilus frisii kutum*) in Iranian waters of the Caspian Sea during 1991-2011. Over this period, the condition factor of female and male Kutum showed decreasing trends. The average condition factor declined from 1.48 in 1991-1992 to 1.29 in 2010-2011 for females and from 1.40 in 1991-1992 to 1.20 in 2010-2011 for males. The instantaneous coefficient of natural mortality was estimated at 0.39/yr and the instantaneous coefficient of fishing mortality varied during the 20-years period between 0.20/yr to 1.04/yr. Biomass estimates of Kutum using biomass-based cohort analysis increased from about 34,700 mt in 1991-1992 to 40,900 mt in 1993-1994, declined to 28,800 in 2001-2002, increased to 56,900 in 2006-2007, and again declined to 42,600 in 2010-2011. The total number of released Kutum fingerlings increased from about 110 millions in 1991 to 400 millions pieces in 2010. Although there is a significantly positive correlation between fingerlings released and recruitments, it appears on the other hand that condition factor is adversely influenced by the number of fingerlings released. Moreover, over the recent period, biomass and catches do not seem to benefit so much from the increasing efforts in fingerlings release. We concluded that more research should be conducted to determine the desirable level of artificial propagation.

RÉSUMÉ. - Programme d'alevinage et évolution de la biomasse et du coefficient de condition du kutum de la mer Caspienne au cours de la période 1991-2011.

Cet article étudie les changements de la biomasse et de l'indice de condition du kutum (*Rutilus frisii kutum*) en relation avec l'amélioration des stocks de l'espèce dans les eaux iraniennes de la mer Caspienne entre 1991 et 2011. Au cours de cette période, le facteur de condition des femelles et des mâles a montré une tendance à la baisse. Le facteur de condition moyen a diminué, passant de 1,48 en 1991-1992 à 1,29 en 2010-2011 pour les femelles et de 1,40 en 1991-1992 à 1,20 en 2010-2011 pour les mâles. Le coefficient instantané de mortalité naturelle a été estimé à 0,39 par an et le coefficient instantané de mortalité par pêche a varié entre 0,198 par an à 1,045 par an durant les 20 ans de l'étude. Les estimations de biomasse du kutum par l'analyse de cohorte basée sur la biomasse a montré une augmentation, passant d'environ 34 700 tonnes en 1991-1992 à 40 900 tonnes en 1993-1994, une diminution à 28 800 tonnes en 2001-2002, une augmentation à 56 900 tonnes en 2006-2007, et enfin une diminution à 42600 en 2010-2011. Le nombre total d'alevins relâchés a augmenté, passant d'environ 110 millions d'individus en 1991 à 400 millions en 2010. Bien qu'il existe une corrélation positive significative entre le nombre d'alevins relâchés et recrutés, il apparaît cependant que le facteur de condition est négativement influencé par le niveau d'alevins relâchés. De plus, sur la période la plus récente, la biomasse et les captures ne semblent pas bénéficier autant des efforts croissant de lâcher d'alevins. Nous concluons que de nouvelles recherches devront être menées pour déterminer le niveau souhaitable de reproduction artificielle.

Key words. - Cyprinidae - *Rutilus frisii kutum* - Caspian Sea - Stock enhancement - Biomass - Recruitment - Condition factor.

The Caspian Kutum, *Rutilus frisii kutum* Kamensky, 1901, is a migratory anadromous fish (Berg, 1946). In Iranian waters of the Caspian Sea, spawning migration of Kutum into rivers occurs from March to April (Adeli Mosabbab and Piri, 2005), depending on water temperature, sea processes and ecological conditions (Valipour and Khanipour, 2006).

Caspian Kutum is a principal species in commercial catches from Iranian waters of the Caspian Sea. According to Valipour and Khanipour (2006), Caspian Kutum has mainly been recorded in the Iranian waters of the Caspian Sea and has rarely been found in the North regions of the Sea and the Volga River. A decrease in the sea water levels from the 1950s has caused a drastic decline in the stocks of Kutum in the Caspian Sea (Valipour and Khanipour, 2006).

Total annual catch of the Caspian Kutum during 1950-1980 ranged from 100 to 2100 mt. Due to sharp decrease

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in stocks of the Caspian Kutum, artificial propagation for enhancing and restocking of the fish has been started by Iran Fisheries Organization (IFO) since 1981. The fingerlings release into the sea has increased from 2 millions in 1981 to more than 140 millions in 2008 (Yousefian and Mosavi, 2008). Subsequently, the catch of Kutum increased to more than 10000 mt during 2000s, and reached its highest level in 2007 (17200 mt). Abdolhay *et al.* (2011) reported that IFO has successfully done the restocking of Kutum in the Caspian Sea, and they concluded that due to the release program, the landings from capture fisheries as well as the number of fishermen had increased. The main objective of the present study was to assess the trends in biomass and condition factor of the Caspian Kutum in relation to the stock enhancement program undertaken in the south of the Sea, and to provide a scientific basis for future discussions about the optimum level of this program.

MATERIALS AND METHODS

Sampling areas were located in the fishing regions of the Iranian coastal areas of the Caspian Sea. There are at present about 130 fishing cooperatives along the coastal zone in three provinces (Golestan, Mazandaran and Guilan). The samples were collected using beach seines operated by the staff of the Inland Water Stocks Research Center, Caspian Sea Ecology Research Center and Inland Water Aquaculture Research Center during fishing seasons (from early October to mid April), during 1991-2011. The fork length was measured to the nearest 0.5 cm and total weight to the nearest 1 g.

Scales were collected from the middle of the body behind the pectoral fins above the hypothetical lateral line and preserved in envelopes for future treatment. The scales from this body area are uniform and well readable. The scales were washed, placed in small covered Petri dishes with tap water. Biological parameters ($K = 0.22$/yr, $t_0 = -0.13$ yr and $L_\infty = 66$ cm) from the previous study (Fazli, 2011) were used as input data in this study.

The condition factor (CF) was calculated using the following equation (Bagenal, 1978):

$$CF = (W / L^3) \text{ x } 100$$

Survival rate (S) was calculated using the catch curve method (Ricker, 1975) to estimate terminal fishing mortalities. To estimate S, age compositions were derived from length composition data collected from the beach seine during 2008-2011, and age-length key in Iranian waters was used as input data. These terminal mortalities were then used as input data for biomass-based cohort analysis estimation of biomass and fishing mortality. The instantaneous coefficient of total mortality (Z) was transformed from the survival rate as:

$$Z = -\ln S$$

The instantaneous coefficient of natural mortality was estimated using Pauly model (Pauly, 1980) with von Bertalanffy growth parameters as below:

$$\mathrm{Ln}(M) = -0.0152 - 0.279\ln(L_\infty) + 0.6543\ln(K) + 0.463\ln(T)$$

where M is the instantaneous coefficient of natural mortality, K is the growth coefficient, T is the mean annual habitat temperature, and T = 14.3°C (Afraei Bandpei *et al.*, 2009).

The instantaneous coefficient of fishing mortality (F) was calculated as: $F = Z - M$

A biomass-based cohort analysis (Zhang and Sullivan, 1988) was used to estimate biomass and instantaneous fishing mortality at age and by year according to the following model equations, assuming that catch is taken instantaneously at mid-year. The biomass of the last year and the last age-class was calculated according to the following equation:

$$B_t = [C_t(F_t + M - G)] / [F_t(1 - e^{-(F_t + M - G)})]$$

and for others:

$$B_{ij} = B_{i+1j+1}e^{(M - G_j)} + C_{ij}e^{(M - G_j)/2}$$

$$F_{ij} = \ln(B_{ij} / B_{i+1j+1}) - M + G_j$$

where B_t is the biomass of the last year and the last age-class, C_t is the catch in weight at last year and last age-class, F_t is the terminal fishing mortality, G_j is the instantaneous coefficient of growth at age j, B_{ij} and B_{i+1j+1} are the biomass at age j and j + 1 in year i and i + 1, C_{ij} is the catch in weight at age j in year i, and F_{ij} is the instantaneous coefficient of fishing mortality at age j in year i. The catch in weight at age for Kutum from 1991-2011, instantaneous coefficient of growth at age, instantaneous coefficient of natural mortality, and terminal fishing mortality were used as input data. The instantaneous coefficient of growth at age (G_j) is calculated according to the following equation:

$$G_j = \ln(W_{j+1} / W_j)$$

where W_j and W_{j+1} are the body weight at age j and j + 1, respectively.

The data on quantities of released fingerling were provided by the IFO (Abdolhay *et al.*, 2011) as well as the statistical data on commercial catches.

Finally, a correlation matrix was calculated between the two decades time series of the five main variables, both observed/registered ('condition factor CF', 'fingerlings released fg-r' and 'catches C') and estimated using the cohort analysis ('Recruitment R which is the biomass for the cohort of age 2 years', 'Biomass B').

RESULTS

During the years 1991-2011, the length and weight of Caspian Kutum ranged from 18 to 70 cm and from 75 to 5750 g, and averaged (± SD) 38.4(± 6.40) cm and 829.4(± 434.7) g, respectively (Tab. I). The average length and weight of females were higher than males for the 20 years except during 1998-1999 (Fig. 1).

Table I. - Mean individual fork lengths and weights of Kutum sampled in Iranian region of the Caspian Sea during the years 1991-2011.

Year	Fork length (cm)			Weight (g)	
	N	Mean ± S.D.	Min.-Max.	Mean ± S.D.	Min.-Max.
1991-1992	5846	41.2 ± 5.99	20-63	1076.2 ± 476.6	100-3500
1992-1993	9189	37.6 ± 6.12	18-70	810.8 ± 452.2	100-5750
1993-1994	6746	38.8 ± 5.27	20-59	867.2 ± 379.5	100-3270
1994-1995	2948	37.4 ± 7.14	19-65	810.1 ± 481.1	100-3500
1995-1996	3620	39.7 ± 6.12	21-61	901.7 ± 401.1	87-3000
1996-1997	4874	38.9 ± 6.88	20-60	898.2 ± 467.4	75-2800
1997-1998	3619	38.7 ± 6.66	19-65	844.8 ± 439.1	94-2600
1998-1999	3129	37.8 ± 7.23	20-63	781.7 ± 417.6	100-3170
1999-2000	4554	37.5 ± 7.85	18-65	775.8 ± 457.6	100-3200
2000-2001	1321	37.6 ± 8.33	20-62	791.3 ± 467.2	100-3625
2001-2002	1388	36.6 ± 6.23	20-57	749.5 ± 492.2	100-2700
2002-2003	1991	37.7 ± 6.02	21-59	746.0 ± 396.9	100-2750
2003-2004	1304	37.8 ± 5.59	20-59	773.1 ± 380.0	75-2600
2004-2005	1031	37.6 ± 5.59	24-55	717.7 ± 344.3	155-2010
2005-2006	3102	37.7 ± 6.36	21-61	775.7 ± 396.0	120-3000
2006-2007	4417	37.7 ± 6.4	18-64	769.1 ± 388.7	95-3045
2007-2008	3503	37.6 ± 6.12	22-64	737.1 ± 379.9	150-3620
2008-2009	3268	38.8 ± 5.25	20-65	777.6 ± 327.5	95-3370
2009-2010	3230	38.8 ± 5.99	21-59	810.9 ± 402.1	120-2890
2010-2011	5088	38.8 ± 6.09	20-62	781.3 ± 381.9	99-2750
Total	74168	38.4 ± 6.40	18-70	829.4 ± 432.7	75-5750

During the years 1991-2011, the CF of female and male Kutum showed a decreasing trend (Fig. 1). The average CF declined from 1.48 in 1991-1992 to 1.29 in 2010-2011 for females and from 1.40 in 1991-1992 to 1.20 in 2010-2011 for males. The average CF values were significantly different between sexes (*t*-test, $t = 44.3$, $p < 0.001$). In addition, we notice that CF exhibits seasonal variations. The monthly average CF of females increased from 1.32 in October to 1.38 in November and decreased to 1.35 in April. For males it increased from 1.32 in October to 1.34 in November and declined to 1.26 in April (Fig. 2).

Total catch of Kutum declined from about 10900 mt in 1991-1992 to 6580 mt in 1999-2000, increased to 17200 mt in 2007-2008, and again declined to 11570 mt in 2010-2011 (Fig. 3). Kutum age ranged from 2 to 9 years. In the age composition, ages 3 and 4 were the largest groups during the years 1991-2011 and represented 25.8 and 28.5% of the catches, respectively.

Based on catch curve method, the annual survival rate (*S*) of the Caspian Kutum was estimated to be 0.25/yr. Given this survival rate, the instantaneous coefficient of total

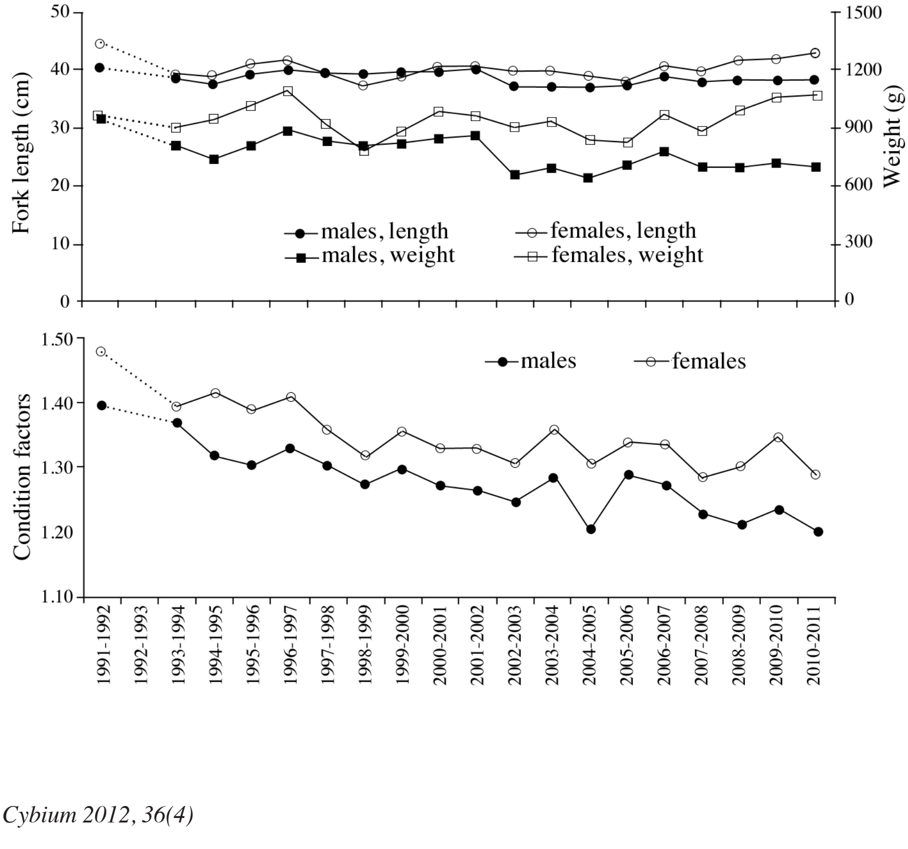

Figure 1. - Mean fork lengths, weights and condition factors (mean ± S.E.) of females and males for Caspian Kutum in Iranian region of the Caspian Sea during 1991-2011.

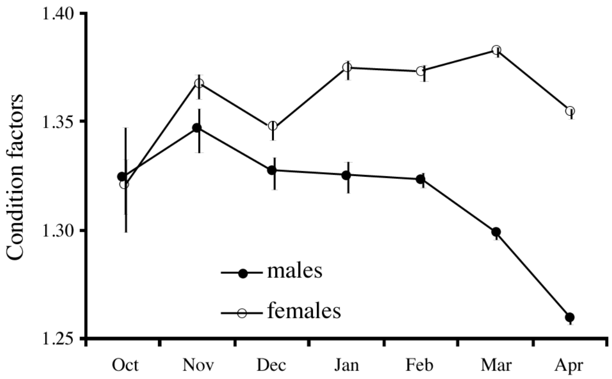

Figure 2. - Monthly condition factors CF (mean ± S.E.) of females and males of Kutum in Iranian waters of the Caspian Sea.

mortality (Z) of Kutum was calculated to be 0.78/yr. Estimate of the instantaneous coefficient of natural mortality for the Caspian Kutum obtained from the Pauly method was 0.39/yr.

Biomass estimates of Kutum, from the biomass-based cohort analysis (Fig. 3) showed increase from about 34,700 mt in 1991-1992 to 40,900 mt in 1993-1994, declined to 28,800 in 2001-2002, increased to 56,900 in 2006-2007, and again declined to 42,600 in 2010-2011. During this period, the average biomass of age 3 represented the highest proportion of the total biomass at 26.9% (10,855 mt), followed by the age 4 biomass (24.3%) and age 2 biomass (16.7%), the latter corresponding to the 'recruitment' cohort. Annual changes in the instantaneous coefficient of fishing mortality varied between 0.20/yr to 1.04/yr (Fig. 3). However, when the two first years of data were removed due to ill computation, the fishing mortality ranged between 0.20/yr and 0.42/yr. With the estimates of instantaneous coefficients of total and fishing mortality, the exploitation ratios for each year were calculated (Fig. 3). During the years 1991-2011 the exploitation ratio of Kutum varied from 0.34 to 0.73 (Fig. 3).

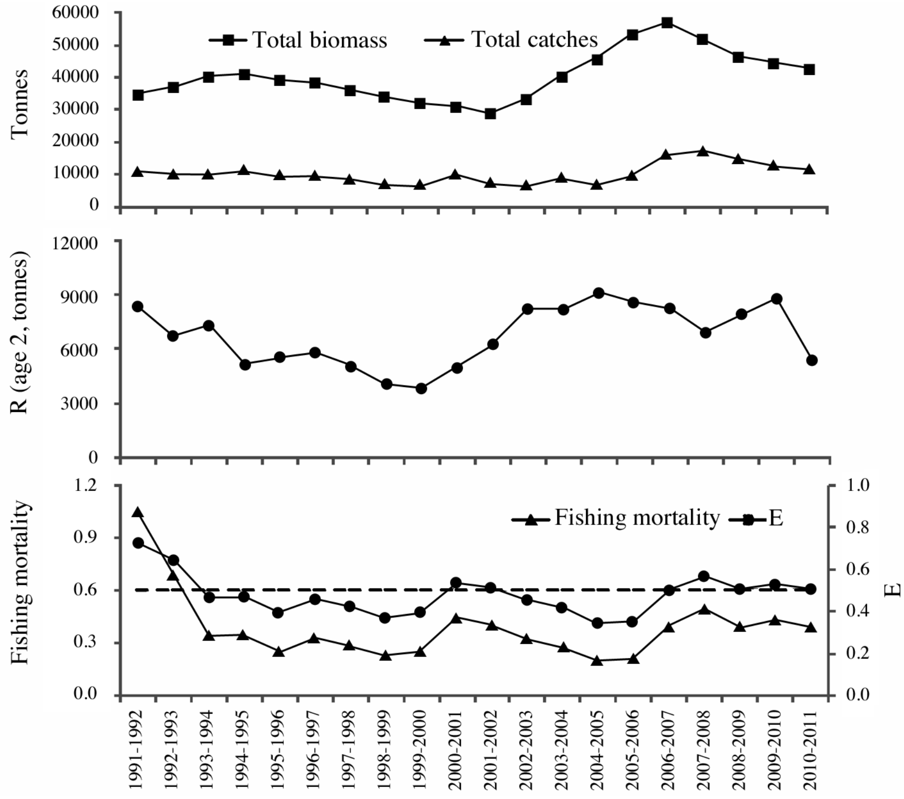

Figure 3. - Total biomass and catch, biomass at age 2 (recruitment = R), fishing mortality and exploitation ratio E of Caspian Kutum in Iranian commercial catches during 1991-2011.

The total numbers of released Kutum fingerlings increased from about 110 million in 1991 to 400 million pieces in 2010 (Tab. II). This increasing trend of fingerlings released into the Sea was significantly correlated with recruitments (age 2) of Kutum in the following years (Tab. III). The correlation between total catch and biomass was also statistically significant. There is a significantly negative correlation between fingerlings released and CF. There was also a significantly negative correlation between estimated recruitment and CF (Tab. III). The CF did not significantly correlate with that of the total catch and biomass. Nevertheless, a slight trend of change of CF was observed when the total biomass increased, as shown by the phase diagram (Fig. 4).

Table II. - Number of Kutum fingerlings released in Iranian waters of the Caspian Sea during the years 1991-2011.

Year	N (10^6)	Year	N (10^6)	Year	N (10^6)
1991	109.8	1998	143.3	2005	229.1
1992	96.6	1999	147.8	2006	174.5
1993	100.0	2000	147.4	2007	262.5
1994	142.7	2001	233.0	2008	187.1
1995	125.1	2002	225.2	2009	270.0
1996	142.1	2003	155.0	2010	400.0
1997	154.4	2004	179.4	2011	270.8

DISCUSSION

Although Molony *et al.* (2003) identified 13 reasons for lack of success in stock enhancement, Abdolhay *et al.* (2011)

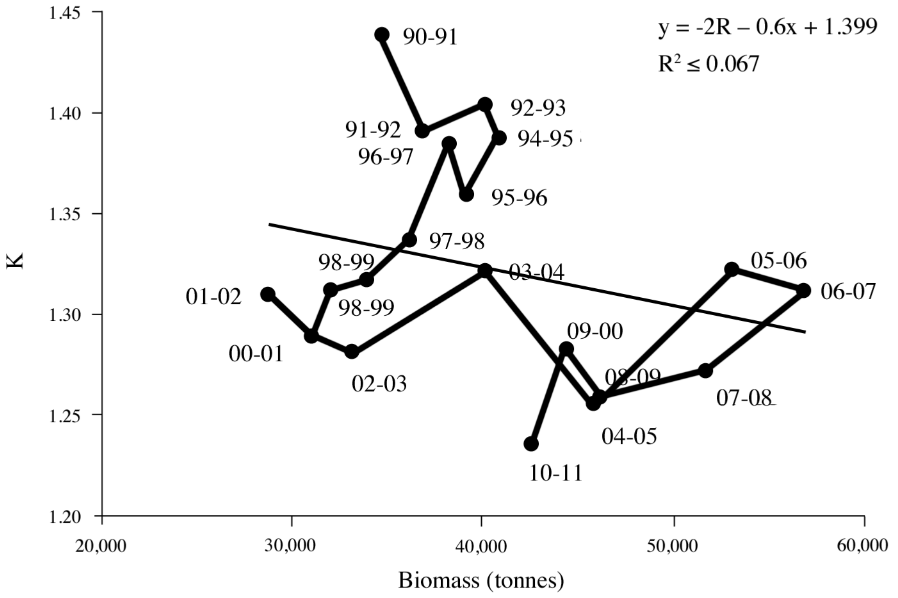

Figure 4. - Relationship between condition factor (CF) and total biomass of Caspian Kutum during 1991-2011.

Table III. - Lower triangular correlation matrix of fingerlings released (fg-r), condition factor (CF), total biomass (B), recruitment (R), and catch (C) of Caspian Kutum during 1991-2011 (n = 20). * Statistically significant correlation at 0.05. ** Statistically significant correlation at 0.01.

Variable	fg-r	CF	R	B	C
fg-r	–				
CF	-0.65**	–			
R	0.58*	-0.48*	–		
B	0.33	-0.26	0.16	–	
C	0.28	-0.13	0.12	0.71**	–

reported that the increase of the landings of Kutum from fisheries in Iranian waters of the Caspian Sea was due to the successful restocking. Similar results were observed in the present study. The increasing trend of released fingerlings was significantly correlated with recruitments in the 1991-2011 period.

For the total biomass of Kutum two periods can be distinguished: 1) the low biomass period of 1991-2002 ranging between 28,800-40,900 mt, and 2) the high 2002-2011 period ranging between 28,800-56,900 mt. Part of these variations in biomass was explained by fishing mortality: the peaks in fishing mortality during 2000-2001 and 2006-2008 were followed by drops in biomass (Fig. 3). We should note, however, that during the years 1991-1992, 2000-2002 and 2006-2011, the estimated exploitation ratio was > 0.5, higher than the rate of 0.5 suggested by Gulland (1983) for maximizing harvest.

Besides, an invasive jellyfish (Ctenophora, *Mnemiopsis leidyi*) appeared in 1999 (Ivanov *et al.,* 2000) in the Caspian Sea and has affected all components of the ecosystem (Roohi *et al*., 2010; Ganjian *et al.,* 2010). More specifically, it negatively affected the two pelagic species (anchovy, *Clupeonella engrauliformis* and bigeye kilka, *C. grimmi* (Fazli *et al*., 2007a, 2009), and positively affected the golden grey mullet and common kilka stocks (Fazli *et al*., 2007b, 2008). Therefore, high increasing trends in biomass of Kutum in the second period could be due to different ecological conditions in the Caspian Sea. According to Kideys *et al*. (2008), there is a significant correlation between chlorophyll *a* concentrations and the biomass of *M. leidyi* in the southern Caspian Sea. These researchers mentioned that by consuming the herbivorous zooplankton, the predatory ctenophore *M. leidyi* may have caused chlorophyll *a* to increase highly. Therefore, after invasion of *M. leidyi*, the biomass of the main food of golden grey mullet (periphyton and detritus) and Kutum (omnivorous feeding) and consequently the biomass of the species increased in the Caspian Sea.

During 1991-2011, the CF of both sexes of Kutum showed a decreasing trend. There were significantly negative correlation between fingerlings released and recruitments with the CF (Tab. III). The different trends for fingerlings, recruitments (also biomass, Fig. 4) and CF suggest that CF may be partly density-dependent, declining at high population sizes due to intra-specific competition. Although other factors such as declining age structure, selection for early maturity under prolonged rates of high mortality or changes in the environment may be considered as possible causal factors impacting on exploited populations (Armstrong *et al*., 1989). The CF of males was highest in November and declined to the lowest level in April. The increased CF for both sexes in November could be due to feeding activity. Afraei Bandpei *et al*. (2010) reported that due to low temperature, the food intake of Kutum declined in winter.

Abdolhay *et al.* (2011) concluded that for protection of Kutum stocks, more effective rehabilitation of natural spawning grounds, and improvement of fishing methods by standardizing the fishing techniques together with increasing the level of artificial propagation should be put into practice. Our results suggest that a phenomenon of density-dependence seems to undermine the positive impact of the fingerlings release program on the status of Kutum population. We conclude that more studies are required prior to increasing the level of artificial propagation in the future.

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